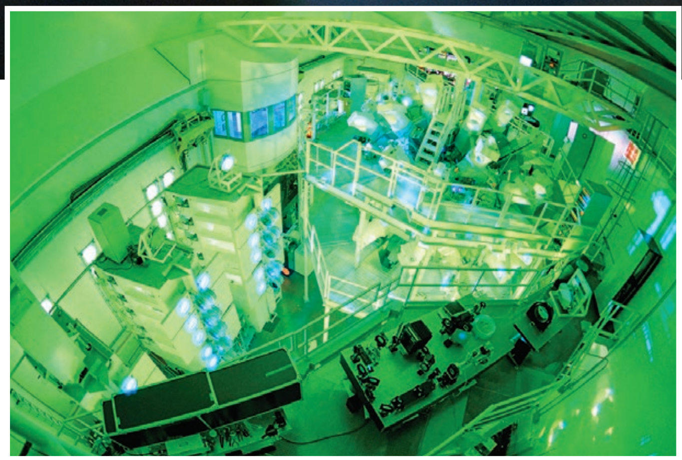

(Top) Inside the target chamber for the OMEGA laser, 60 laser beams converge on a millimeter-sized target capsule to produce an imploding, nuclear-fusion supporting plasma at a temperature of more than 200 million kelvins. (Bottom) The OMEGA target bay bathed in its own light during a target shot.
CREDIT: Eugene Kowaluk/University of Rochester Laboratory for Laser Energetics

SPOTLIGHTS

No Help for the Primordial Particle Soup

IN THE FIRST MINUTES OF THE BIG BANG, AS THE UNIVERSE expanded and cooled, there was a brief window when the conditions were right for the nuclear fusion of hydrogen into heavier atomic nuclei. During that episode in cosmic history, known as big bang nucleosynthesis (BBN), it was hot enough for fusion to occur but not so hot that the resulting nuclei would disintegrate. And astronomical measurements of the primordial abundances of key isotopes produced by BBN—three isotopes of hydrogen and two of helium—match the predictions of the big bang theory to exquisite precision. However, the only other element produced by BBN in any observable quantity, lithium, presents a discrepancy. For its more common isotope, lithium-7, the discrepancy is manageable, but for lithium-6, it's enormous. Observations exceed theoretical predictions by three orders of magnitude.

Alex Zylstra, a Los Alamos plasma physicist, thought he could help resolve the lithium-6 conundrum. He and others in the field knew that if a particular BBN reaction, fusing helium-3 with hydrogen-3 (also called tritium), were more active than anyone thought, it could overproduce lithium-6. And earlier measurements of that reaction rate were suspect; they were inconsistent and substantially overshot realistic BBN conditions by relying on high-energy accelerators to produce the fusion reactions instead of lower-energy collisions between nuclei in plasma.

So Zylstra and collaborators developed a more realistic alternative, using an advanced research facility funded by the Department of Energy (DOE), the OMEGA laser at the University of Rochester's Laboratory for Laser Energetics, to heat a mixture of tritium and helium-3 to BBN-appropriate temperatures. In a pulse lasting less than a billionth of a second, sixty powerful lasers converged on the isotope mixture, generating a dramatic implosion to deliver the necessary heating. (Zylstra also conducts similar fusion experiments at another laser-implosion facility, the bigger and more powerful National Ignition Facility, or NIF, at Lawrence Livermore National Laboratory.)

But rather than solving the lithium-6 mystery, Zylstra's experiment ended up compounding it. The measurements convincingly showed that the reaction rate was too low to generate all the excess lithium-6, making it more likely that the troublesome isotope is synthesized elsewhere by some as-yet undiscovered process, perhaps taking place inside early stars. However, the experiment firmed up the tritium-helium-3 reaction rate, showing that it had been inaccurately reported in previously published BBN calculations. And perhaps more importantly, it demonstrated for the first time how plasma-fusion laser facilities like OMEGA and NIF, primarily developed for research supporting stewardship of the nation's nuclear-weapons arsenal, can be double-purposed to benefit nuclear astrophysics research as well. LDRD

—Craig Tyler